

EPILITHIC PHYCOFLORA ON MONUMENTS. A SURVEY OF SAN ESTEBAN DE RIBAS DE SIL MONASTERY (OURENSE, NW SPAIN)

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ABSTRACT — The first data on the algal flora of the granitic walls from San Esteban de Ribas de Sil Monastery (NW Spain) are given. The algae were studied by means of cultures. A total of 31 taxa have been identified, comprising 17 *Cyanophyta*, 13 *Chlorophyta* and 1 *Heterokontophyta*. *Geminella minor* (Nägeli) Heering, *Prasiococcus calcarius* (Boye-Petersen) Vischer and *Trentepohlia monilia* De Wildeman, are new records for Spain.

RÉSUMÉ — Les premiers renseignements sur la flore algale des murs de granit du Monastère de San Esteban de Ribas de Sil (NW Spain) sont fournis ici. Les algues ont été étudiées en cultures. 31 taxons ont été identifiés: 17 *Cyanophyta*, 13 *Chlorophyta* et 1 *Heterokontophyta*. Les espèces *Geminella minor* (Nägeli) Heering, *Prasiococcus calcarius* (Boye-Petersen) Vischer et *Trentepohlia monilia* De Wildeman, sont nouveaux pour l'Espagne.

KEY WORDS: aerial algae, Building biodeterioration, Galicia, Spain

INTRODUCTION

Stone biodeterioration has been the subject of numerous studies (Webley *et al.*, 1963; Palleni & Curri, 1968; Krumbein, 1972; Marathe & Chaudhari, 1975; Van der Molen *et al.*, 1980; Anagnostidis *et al.*, 1983; Koestler *et al.*, 1985; Ortega-Calvo *et al.*, 1991, 1993; Noguerol Seoane & Rifón Lastra, 1995, 1996a, b). On building walls, besides an evident colonization by mosses, lichens and vascular plants, different microorganisms (bacteria, algae and fungi) are present. The first pioneers in the colonization of the walls are algae, mainly blue-green and green algae (Treub, 1888). These plants could be accounted among the factors responsible for the progressive mechanical degradation of the stone. They are the cause of the spots and crusts on the wall (Starks & Shubert, 1982; Ortega Calvo *et al.*, 1991).

The present work is an extension of our research (Noguerol Seoane & Rifón Lastra, 1995, 1996a, b) on the epilithic phycoflora on interesting historic monuments

from Galicia (NW Spain) and its possible role in granitic biodeterioration. San Esteban de Ribas de Sil Monastery stands in a rural environment of the Ourense province (NW Iberian Peninsula, Map 1) at 42°25'N and 8°25'W and 230 m of altitude; according to the Papadakis' classification (1966), it has a temperate Mediterranean climate, with an average annual temperature of 13.7° C. The average temperature of the coldest month (December) is 6.2° C and that for the average hottest (July) is 22.3° C. Average annual precipitation is 1,494 mm, minimum in July with 24 mm and maximum in December with 217 mm (Carballeira *et al.*, 1983). The granitic walls of the Ribas de Sil Monastery are colonized by an important algal contingent, sometimes producing obvious coloured spots.

MATERIAL AND METHODS

The samples were scraped aseptically from the granitic exterior walls in November 1994. They were immediately placed in petri dishes with specific enrichment media [BBM (Bischoff & Bold, 1963)], solidified with 1.2% agar. Part of the material was collected in sterile test-tubes, to be used in direct observations with an optical microscope.

The cultures were incubated in a constant temperature chamber (18° C) with 12/12 hours light/darkness cycle and light intensity of 1,500 lux. They were examined after 15 days incubation. The monoalgal cultures have been carried out in order to study growth and reproduction cycles.

RESULTS

Two asterisks indicate new records for Spain, and one asterisk new records for Galicia.

CYANOPHYTA

Chroococcus minor (Kützing) Nägeli (Fig. 1)

Cells 3.2-4 µm in diameter.

Chroococcus turgidus (Kützing) Nägeli (Fig. 2)

Cells with sheath 9.6-18 µm in diameter, without sheath 8-16 µm.

Gloeocapsa dermochroa Nägeli (Fig. 3)

Cells with sheath 2.7-4.3 µm in diameter, without sheath 1.3-3.1 µm.

Synechocystis pcvalekii Ercegovic (Fig. 4)

Cells 2.5-3 µm in diameter.

Chlorogloea microcystoides Geitler (Fig. 5)

Thallus up to 160 µm. Cell 1.6-4 µm in diameter.

Myxosarcina chroococcoides Geitler (Fig. 6)

Colonies 14.6-25.3 µm in diameter. Cells 3.5-6 µm in diameter.

Lyngbya allorgei Frémy (Fig. 7)

Filaments 4 µm broad. Cells 4 × 2.8-4 µm.

**Lyngbya diguetii* Gomont (Fig. 8)

Filaments 2.3 µm broad. Cells 1.6 × 0.8-1.2 µm.



Map 1. San Esteban de Ribas de Sil Monastery. Geographic location.

**Phormidium soveolarum* (Montagne) Gomont (Fig. 9)

Filaments 1.6 µm broad. Cells 1.6 × 1.2-2.3 µm.

**Phormidium cf. jenkelianum* Schmidle (Fig. 10)

Thallus mucilaginous, bright blue-green. Filaments entangled, 3.2 µm broad with a thin sheath. Trichomes constricted at the cross-walls, 3.2 µm broad. Cells 1.6 µm long. Apical cell rounded, without calyptra. Trichome width and cell length are slightly bigger than those on the original description, although the cell w/l ratio remains unchanged.

Phormidium luridum (Kützing) Gomont (Fig. 11)

Filaments 1.6 µm broad. Cells 1.6 × 1.8 µm.

**Phormidium uncinatum* (Agardh) Gomont (Fig. 12)

Filaments 6.6-7.2 µm broad. Cells 5.6-6 × 0.8-2 µm.

Anabaena sp. (Fig. 13)

Trichomes free living, blue-green, irregularly coiled, with a sheath more or less diffluent or without it. Cells spherical to short barrel-shaped, 3.2 µm broad, 1.6-4 µm long. Heterocysts intercalary, subspherical to cylindrical, 4 µm broad, 4-7 µm long. Akinetes were not observed.

Nostoc microscopicum Carmichael ex Bornet & Flahault (Fig. 14)

Colonies up to 350 µm in diameter. Cells 4.6-6.5 × 3.7-6.4 µm. Heterocysts 6.5-8 µm in diameter.

Plectonema sp. (Fig. 15)

Filaments flexuous, 2.7 µm broad, with false geminate branches and a very thin and hyaline sheath. Trichomes constricted at the cross-walls. Cells blue-green, 1.3-2.6 µm long. Reproduction by hormogones.

It could be *P. murale* Gardner or *P. gracillimum* (Zopf) Hansgirg. An accurate identification was impossible due to the scarce amount of our material and the close similarity between both taxa.

**Tolypothrix byssoides* (Berkeley ex Bornet & Flahault) Kirchner (Fig. 16)

Filaments 6.6-16 µm broad. Cells 5.3-14.6 × 1.3-5.3 µm. Heterocysts 8-10.6 × 8 µm.

Tolypothrix sp. (Fig. 17)

Filaments in masse, blue-green, 9.3 µm broad with a thin firm and hyaline sheath, not attenuated at the ends. False branches geminate, prostrate. Trichomes constricted at the cross-walls, 7.3 µm broad. Cells 4-5.3 µm long. Heterocysts intercalary and terminal, single, oval, 9.3 µm broad, 9.3-10.6 µm long. We have not found any species whose morphological characteristics fits those in our specimens.

CHLOROPHYTA

Bracteacoccus minor (Chodat) Petrová (Fig. 18)

Cells 6-9.6 µm in diameter. Zoospores 2.5 × 5.3 µm.

**Trebouxia anticipata* Ahmadjian ex Archibald (Fig. 19)

Cells 9.4-13.3 µm in diameter.

Chlorella vulgaris Beijerinck (Fig. 20)

Cells 6-8.8 µm in diameter.

Choricystis chodatii (Jaag) Fott (Fig. 21)

Cells 3-3.5 × 7-7.1 µm.

**Keratococcus bicaudatus* (A. Brown) Boye-Petersen (Fig. 22)

Cells 3.7-5 × 16.2-22.5 µm.

****Geminella minor** (Nägeli) Heering (Fig. 23)

Filaments 5.3 µm broad, with sheath 9.3 µm. Cells 6.6-13.6 µm long.

Klebsormidium flaccidum (Kützing) Silva, Mattox & Blackwell (Fig. 24)

Filaments 6-10.6 µm broad. Cells 6-12 µm long.

Klebsormidium subtilissimum (Rabenhorst) Silva, Mattox & Blackwell (Fig. 25)

Filaments 4-5 µm broad. Cells 8-10 µm long.

Stichococcus bacillaris Nägeli (Fig. 26)

Cells 2.7-3.5 × 5.3-9 µm.

Stichococcus minutus Grintzescu & Peterfi (Fig. 27)

Cells 2.5-3 × 4-4.5 µm.

****Prasiococcus calcarius** (Boye-Petersen) Vischer (Fig. 28)

Cells 4.8-9.6 µm broad. Aplanospores 4-5 µm broad.

***Desmococcus vulgaris** Brand (Fig. 29)

Basal cells 6.6-9.3 µm in diameter. Filaments 2.6-4 µm broad, long cells 6.6-14.6 µm.

****Trentepohlia monilia** De Wildeman (Fig. 30)

Cells barrel-shaped 13.3-18 × 14.6-20 µm to spherical 12.6-26 µm in diameter.

In septum 6.6-10.6 µm. Sporangia 20-25 µm in diameter.

HETEROKONTOPHYTA

Navicula atomus (Nägeli) Grunow (Fig. 31)

Valves 3-3.5 × 7-9 µm, 20-28 striae per 10 µm.

DISCUSSION

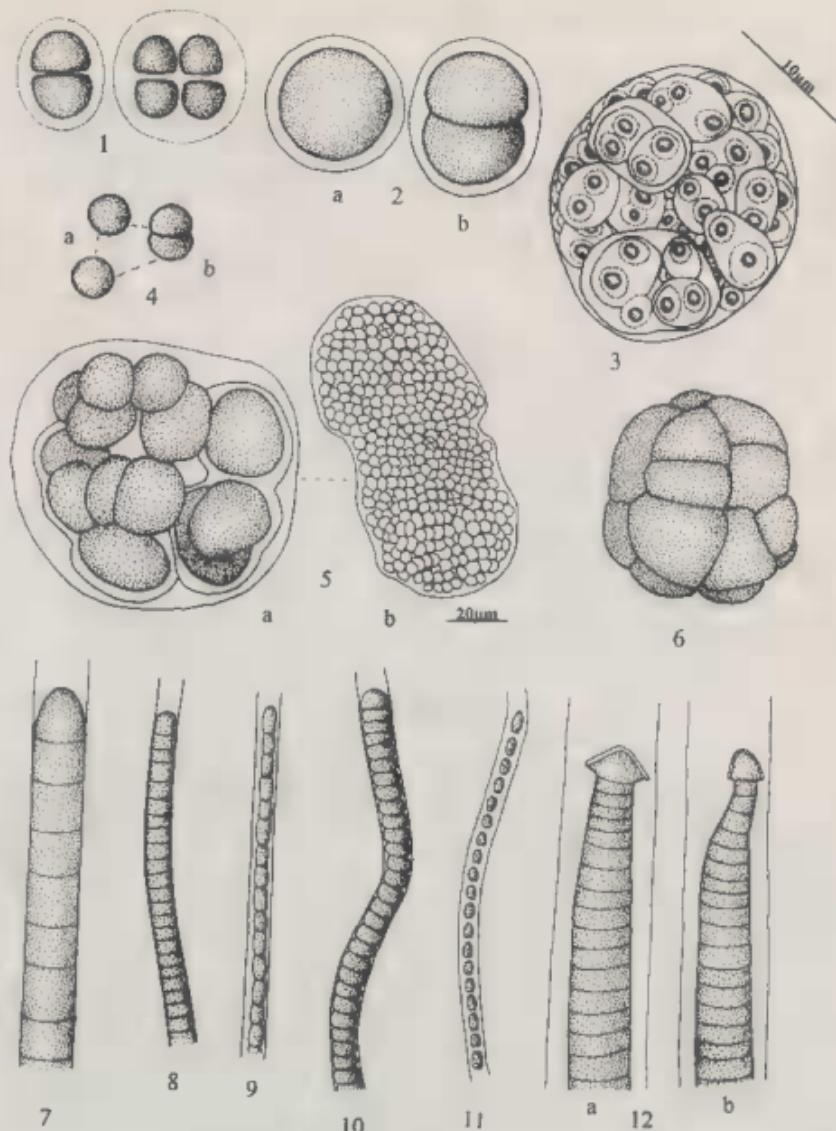
The walls of San Esteban de Ribas de Sil Monastery have an important vegetal cover, especially on the north façade. Among the epilithic algal communities found, a great abundance of blue-green and green algae has been revealed.

The largest and most colourful spots (green, white, blackish and reddish) are due to protonemata and green algae, lichens, blue-green algae (sometimes) and *Trentepohlia*, respectively. The green mat developing in the lower parts of walls facing North is mainly due to protonemata. In higher reaches, spots of the same colour usually are caused by protonemata, *Klebsormidium*, *Stichococcus* and *Prasiococcus*.

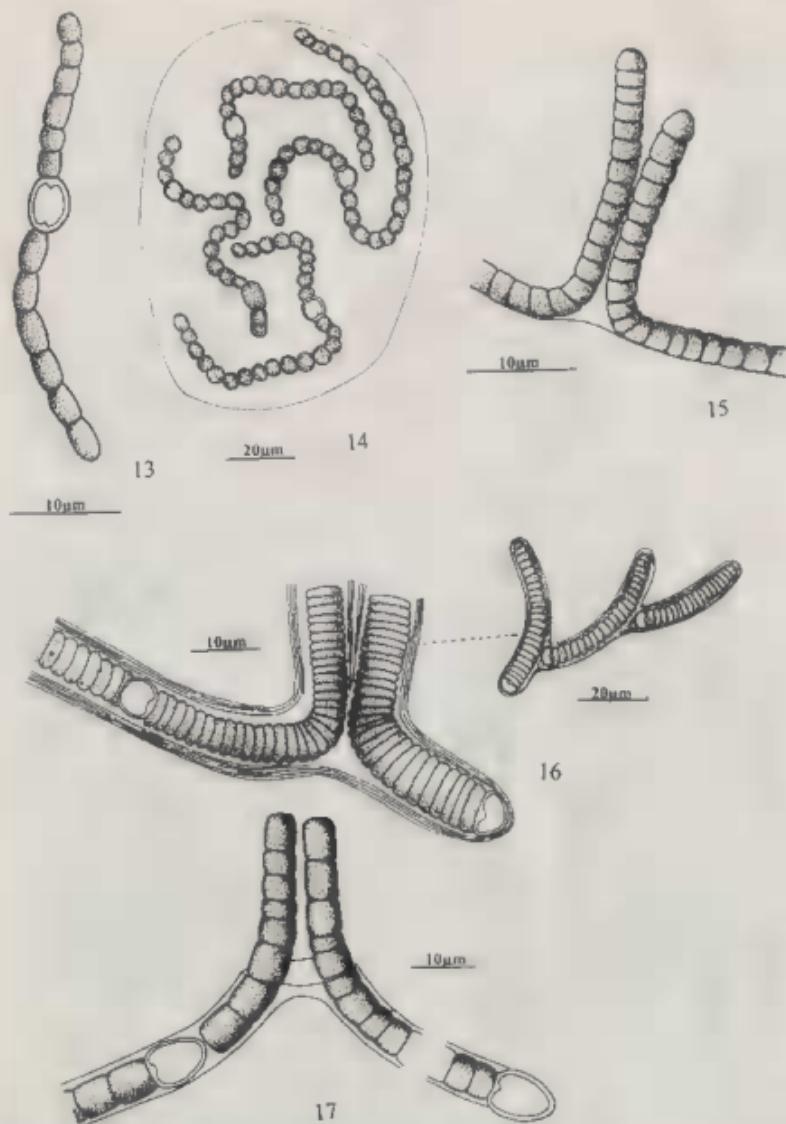
Large deep grey patches are also very abundant, particularly in cloister walls. While the abiotic ones are possibly due to some process affecting granite (some component of the rock may be dissolved, mobilized and eventually precipitated on the surface), the biotic ones, although looking virtually the same, are produced by blue-green algae.

According to Booth (1941), Schwabe & Behre (1971) and Broady (1981), they are cosmopolite species. *Chroococcus minor*, *Gloeocapsa dermochroa* and *Phormidium foveolarum*, are known in fresh water, thermal springs and also on buildings with different substrata: marble of Athens Parthenon and granite in Santiago and San Francisco's churches of Betanzos (NW Spain) (Anagnostidis *et al.*, 1983; Noguerol Seoane & Rifón Lastra, 1996a).

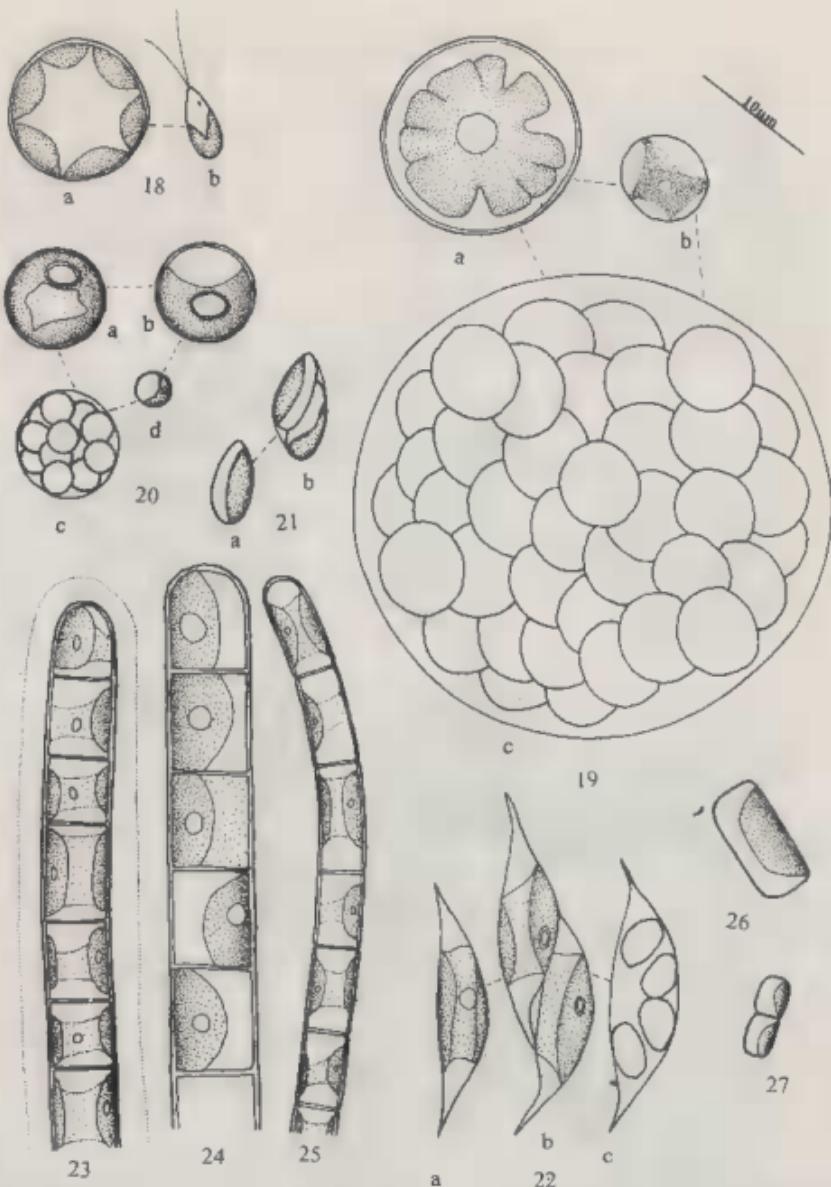
Nostoc microscopicum, *Phormidium* cf. *jenkelianum*, *Tolypothrix hyssoides* and the green algae *Bracteacoccus minor*, *Desmococcus vulgaris*, *Klebsormidium flaccidum*, *K. subtilissimum*, *Prasiococcus calcarius*, *Stichococcus bacillaris*, *S. minutus*, *Trebouxia*



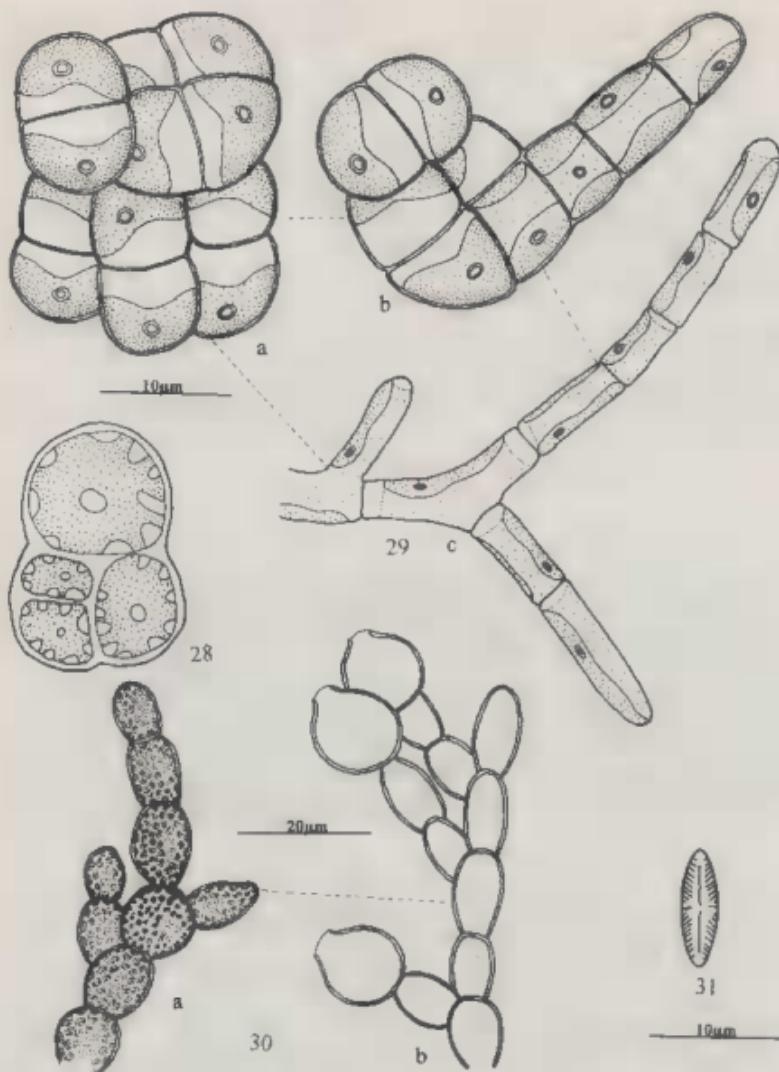
Figs 1-12. Fig. 1. *Chroococcus minor*. Fig. 2. *Chroococcus turgidus*: a, vegetative cell; b, division cells. Fig. 3. *Gloeocapsa dermochroa*. Fig. 4. *Synechocystis pevilekii*: a, vegetative cells, b, division cells. Fig. 5. *Chlorogloea microcystoides*: a, cell arrangement in a young colony; b, general view of a developed colony. Fig. 6. *Myxosarcina chroococcoides*. Fig. 7. *Lyngbya allorgei*. Fig. 8. *Lyngbya diguetii*. Fig. 9. *Phormidium foveolarum*. Fig. 10. *Phormidium cf. jenkellianum*. Fig. 11. *Phormidium luridum*. Fig. 12. *Phormidium uncinatum*.



Figs 13-17. Fig. 13. *Anabaena* sp. Fig. 14. *Nostoc microscopicum*. Fig. 15. *Plectonema* sp. Fig. 16. *Tolypothrix byssoidaea*. Fig. 17. *Tolypothrix* sp.



Figs 18-27. Fig. 18. *Bracteacoccus minor*: a, vegetative cell; b, zoospore. Fig. 19. *Trebouxia anticipata*: a, vegetative cell; b, autospore; c, sporangium. Fig. 20. *Chlorella vulgaris*: a, b, vegetative cells; c, sporangium; d, autospore. Fig. 21. *Choricystis chodatii*: a, vegetative cell; b, autospores formation. Fig. 22. *Keratococcus bicaudatus*: a, vegetative cell, b, vegetative division; c, autospores formation. Fig. 23. *Geminella minor*. Fig. 24. *Klebsormidium flaccidum*. Fig. 25. *Klebsormidium subtilissimum*. Fig. 26. *Stichococcus bacillaris*. Fig. 27. *Stichococcus minutus*.



Figs. 28-31 Fig. 28. *Prasiococcus calcareus*. Fig. 29. *Desmococcus vulgaris*: a, b, cubical groups of cells; c, filament. Fig. 30. *Trentepohlia monilia*: a, fragment of the thallus in vegetative stage; b, fragment of the thallus with empty sporangia. Fig. 31. *Navicula atomus*, front view.

anticipata and *Trentepohlia monilia*, are typical algae from aerial environment. With the exception of *Phormidium cf. jenkelianum* and *Desmococcus vulgaris*, the other taxa have already been recorded on monument walls (Lefèvre, 1974; Schlichting, 1975; Broady, 1979; Ortega-Calvo *et al.*, 1993; Noguerol Seoane & Rifón Lastra, 1995, 1996a, b).

As previously observed on the churches of Santiago and S. Francisco in Betanzos (Noguerol Seoane & Rifón Lastra, 1996a), *Trentepohlia* disintegrates the stone. The rock surface under *Trentepohlia* spots is easily broken into small pieces when sampling.

The presence of blue-green algae is important in biodeterioration study. The gelatinous sheaths can shrink or swell depending on the humidity of the environment, representing a possible factor for the gradual destruction of rock (Friedmann, 1971; Golubic, 1973; Anagnostidis *et al.*, 1983).

The unusual presence of basophilic taxa (e.g. *Prasiococcus calcareus*) on granite could be due to the imput of limestone mortar and nutrients coming from bird droppings (Broady, 1979).

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REFERENCES

- ANAGNOSTIDIS K., ECONOMOU-AMILLI A. & ROUSSOMOUSTAKAKI M., 1983 — Epilithic and chasmolithic microflora (*Cyanophyta, Bacillariophyta*) from marbles of the Parthenon (Acropolis-Athens, Greece). *Nova Hedwigia* 38: 227-287.
- BISCHOFF H.W. & BOLD H.C., 1963 — Some soil algae from Enchanted Rock and related algae species. *Phycological Studies* 6318: 1-95.
- BOOTH W.E., 1941 — Algae as pioneers implant succession and their importance in erosion control. *Ecology* 22: 38-46.
- BROADY P.A., 1979 — The terrestrial algae of Signy Island, South Orkney Islands. *British Antarctic Survey Bulletin* 98: 1-117.
- BROADY P.A., 1981 — Ecological and taxonomic observations on subaerial epilithic algae from Princess Elizabeth Land and MacRobertson Land, Antarctica. *British Phycological Journal* 16: 257-266.
- CARBALLEIRA A., DEVESA C., RETUERTO R., SANTILLÁN E. & UCIEDA F., 1983 *Bioclimatología de Galicia*. Vigo, Fundación Pedro Barrié de la Maza. 391 p.
- FRIEDMANN E.I., 1971 — Light and scanning electron microscopy of the endolithic desert algal habitat. *Phycologia* 10: 411-428.
- GOLUBIC S., 1973 — The relationship between blue-green algae and carbonate deposits. In: Carr N.G. & Whitton B.A. (eds), *The Biology of Blue-Green Algae*. London, Blackwell. pp. 434-472.
- KOESTLER R.J., CHAROLA A.E., WYPYSKI M. & LEE J.J., 1985 — Microbiologically induced deterioration of dolomitic and calcitic stone as viewed by scanning electron microscopy. In: Felix G. (ed.), *Proceedings V International Congress on Deterioration and Conservation of Stone*. Vol. II, Lausanne, Polytechniques Romandes, pp. 617-625.
- KRUMBEIN W.E., 1972 — Rôle des microorganismes dans la genèse, la diagenèse et la dégradation des roches en place. *Revue d'Ecologie et Biologie du Sol* 9: 283-319.
- LEFÈVRE M., 1974 — La "Maladie Verte" de Lascaux. *Studies in Conservation* 19: 126-156.
- MARATHE K.V. & CHAUDHARI P.R., 1975 — An example of algae as pioneers in the lithosphere and their role in rock corrosion. *Journal of Ecology* 63: 65-70.

- NOGUEROL SEOANE A. & RIFÓN LASTRA A.B., 1995 — Aportación al conocimiento de la ficoflora epilitica en monumentos del N.O. de España. Estudio del Monasterio de Samos (Lugo). *Anales del Jardín Botánico de Madrid* 54 (1): 37-42.
- NOGUEROL SEOANE A. & RIFÓN LASTRA A.B., 1996a — Epilithic phycoflora on two monuments of Historic-Artistic interest from Galicia (NW Spain). *Degradation and Conservation of Granitic Rocks in Monuments. Protection and Conservation of European cultural heritage. European Commission* 5: 417-421.
- NOGUEROL SEOANE A. & RIFÓN LASTRA A.B., 1996b — Aportación al conocimiento de la ficoflora epilitica en monumentos del N.O. de España. Estudio del Monasterio de Sobrado dos Monxes (A Coruña). XI Simposio Nacional de Botánica Criptogámica. Abstracts, pp. 85-86.
- ORTEGA-CALVO JJ., HERNÁNDEZ-MARINÉ M. & SÁIZ-JIMÉNEZ C., 1991 — Biodeterioration of building materials by cyanobacteria and algae. *International Biodeterioration and Biodegradation* 28: 165-185.
- ORTEGA-CALVO JJ., HERNÁNDEZ-MARINÉ M. & SÁIZ-JIMÉNEZ C., 1993 — Cyanobacteria and algae on historic buildings and monuments. In: Garg Neelima Garg K.L. & Mukerji K.G. (eds), *Recent Advances in Biodeterioration and Biodegradation*, vol. I. Calcutta, Naya Prokash, pp. 173-203.
- PALLENI A. & CURRI S.B., 1968 — Biological aggression of works of art in Venice. In: Romanowski V. (ed.), *Biodeterioration of Materials*. Amsterdam, Elsevier, pp. 356-363.
- PAPADAKIS J., 1966 — *Climates of the World and their Agricultural Potentialities*. J. Papadakis, Buenos Aires, 504 p.
- SCHLICHTING H.E., 1975 — Some subaerial algae from Ireland. *British Phycological Journal* 10: 257-261.
- SCHWABE G.H. & BEHRE K., 1971 — Ökogenese der Insel Surtsey 1968 bis 1970. *Naturwissenschaftliche Rundschau* 24: 513-519.
- STARKS T.L. & SHUBERT L.E., 1982 — Colonization and succession of algae and soil-algae interactions associated with disturbed areas. *Journal of Phycology* 18: 99-107.
- TREUB M., 1888 — Notice sur la nouvelle flore de Krakatau. *Annales du Jardin Botanique de Buitenzorg* 7: 213-223.
- VAN DER MOLEN J., GARTY J., AARDEMA B.W. & KRUMBEIN W.E., 1980 — Growth control of algae and cyanobacteria on historical monuments by mobile UV Unit (MUVU). *Studies in Conservation* 25: 71-77.
- WEBLEY D.M., HENDERSON M.F.K. & TAYLOR I.F., 1963 — The microbiology of rocks and weathered stones. *Journal of Soil Science* 14: 102-111.